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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Our experiments and developments are encouraging; digitally derived contours satisfy mapping requirements with limited cartographic interpretations,

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The advantages of computer drawn contours are three-fold: (1) Man/machine hours are reduced; (2) we are able to take advantage of the digital terrain elevation data base; and (3) there is less requirement for cartographer interpretation of topography.

EXPERIENCES WITH DIGITAL TERRAIN ELEVATION DATA CONTOURING PROGRAMS

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BIOGRAPHICAL SKETCH

Mr. Alderman received his bachelors degree in mathematics in 1967 from Southern State College in Arkansas. He received his masters degree in Civil Engineering (Photogrammetry) in 1971 from the University Of Illinois. His mapping career includes experience as a cartographer, analog and analyical Stereo Plotters, Aerial Photo-Inspector. instructor at the DMAIAGS Cartographic School and project engineer in the DMAIAGS Bolivia Project. He is currently assigned to the Cartography Department Air Target Materials, Nav/Plan Division Technical Office. Mr. Alderman is a member of the American Society of Photogrammetry and the American Congress on Surveying and Mapping.

ABSTRACT

The DMA digital terrain elevation data base has been expanding steadily since its inception. With increasing coverage there has been a greater opportunity to apply this data, including the automatic derivation of contours from digital elevation data for aerospace charts.

Our experiments and developments are encouraging; digitally derived contours satisfy mapping requirements with limited cartographic interpretations, corrections and editing. However, each successful refinement reveals many new aspects to be explored. Smoothing algorithms reduce man-hours spent in "light table interface." Present developments also examine techniques for generalizing detail for charting at smaller scales.

The advantages of computer drawn contours are threefold: (1) Man/Machine hours are reduced, (2) we are able to take advantage of the digital terrain elevation data base, and (3) there is less requirement for cartographer interpretation of topography.

INTRODUCTION

The role of Digital Cartography is increasing at the Defense Mapping Agency Aerospace Center (DMAAC). In areas where a suitable data base exists, we are creating contours from Digital Terrain Elevation Data (DTED). Cartographers use a computer program which constructs contours from a rectangular array of elevation posts. The design of a hardware/software combination requires a comprehensive view of building the relief data base, manipulating the data to satisfy cartographic requirements and constructing the contours.

There are five interrelated processes in manipulating hypsometric data.

1. Profiles to matrix

2. Contours to matrix

3. Smoothing

4. Generalizing

5. Matrix to contours

Elevation data are collected by either automatically scanning profiles from a photogrammetric model on an analytical stereo plotter or by digitizing contours from an existing map. These data are then transformed to the DTED matrix. A smoothing algorithm automatically eliminates certain types of errors which enter in the collection process. Generalizing selectively retains the geomorphic character of the surface while thinning the elevation data for compilations at smaller scales. Finally, the contouring algorithm converts the elevation matrix data to linear contours.

ORGANIZATION OF THE DATA BASE

The Defense Mapping Agency has a very extensive digital cartographic data base. Relief information is stored into the Digital Terrain Elevation Data (DTED) base. Heights are represented in a rectangular array of elevation posts. The rows lie along geographic parallels and the columns coincide with meridians. Three seconds of arc separate the rows of elevation posts. Longitude spacing varies from three seconds to eighteen seconds in five zones. (see figure 1).

The DTED base is a practical format for storing data. Computer algorithms are designed to begin with matrix elevation data and construct graphic or video displays for human interpretation. A data base of linear contours would not have as universal an application.

OPERATIONS WITH ELEVATION DATA

Profiles to matrix

Our most accurate data have been developed photogrammetrically. An automated analytical stereo plotter scans profiles on an absolutely oriented stereo model. A computer algorithm interpolates three second elevation posts from the surface defined by the X, Y and Z profile coordinates generated on the analytical plotter (see figure 2).

Contours to Matrix

Relief data from existing map source can be collected by digitizing contours. A cartographer can digitize the contours by following each one with a hand-held cursor or a contour manuscript can be scanned automatically. When contours are digitized manually, the cartographer labels each data string as he goes. The scanned contours are linearized then labeled on an interactive graphic system. The contours to matrix computer algorithm converts the contours to profiles with irregulary spaced elevation points erected where the profiles cross contours. Each DTED elevation post is interpolated from surrounding profile points. (see figure 3).

Geomorphic data (highest elevations, ridge lines and valleys), can be used to insure that the terrain data is logical and prevent the loss of critical features. The geomorphic data is used with both cartographic and photogrammetric determinations.

Smoothing

Products generated from unedited data often show biases. The scan lines from the photogrammetric profiles or the automatic digitizer are often evident. Blunders, called spikes, somehow find their way into the data set. The biases are normally within the tolerance of accurate contours, but are not cartographically acceptable. The spikes must be eliminated. A smoothing algorithm or filter is used to automatically eliminate the biases and spikes.

The two basic premises of the filter are that there are limits to the magnitude of abrupt changes in topography and that along a profile natural terrain does not have systematically repeating undulations. The filter effectively eliminates the biases and spikes. However, if it is not used carefully, it can crop off peaks and ridges and fill in valleys. Another problem we have observed is that in a high relief area adjacent to a flat area the filter can add ripples to the flat area.

Generalizing

We generalize features to remove superfluous character and to reduce the amount of data being processed. The difficulty encountered is programming the computer to simulate cartographic judgement. Most of our experiences in constructing contours have been for charts at a scale of 1:200,000. The three second data base, when reduced to this scale, very closely complies with the accuracy requirements for 1:200,000 maps. Elevation posts, roughly 100 meters apart at ground scale are one half milimeter apart at map scale.

It is also desirable to construct contours for smaller scale charts from the same data base. However, when we maintain line weight and reduce scale, features which are small with respect to the width of the contour lines no longer contribute information, but only add noise. Furthermore, by reducing the number of data points, computation time is proportionally reduced. A chart compiled at scale 1:1,000,000 requires only one twenty-fifth (1/25) the amount of data as a chart over the same area at 1:200,000 scale.

The data base can be generalized by retaining only every fifth row and column. The danger here is that critical elevations, such as mountain tops, ridgelines and drainage features might be lost or displaced. To prevent the loss of critical elevations, geomorphological data is re-entered into the data base to restore character.

Matrix to Contours

Linear contours are constructed from the refined matrix data. The chart is divided into convenient sized units called sectors. The size of the sector will vary according to the user's requirements and the scale of the compilation. Generally, we use a six minute rectangular sector for a 1:200,000 scale chart. This is a 121 by 121 matrix of elevation posts.

Within the sector, the computer searches for the highest and lowest elevation posts and attempts contours only within those limits. The four corners of each square of elevation posts are checked to see if the contour being drawn passes through that square. If the contour exists for the square, that segment of the line will be stored (see figure 4). A second computer algorithm collects the individual line segments and integrates them into a continuous line for each contour. The final step performed in the program prior to plotting is positioning the contours on the desired projection.

THE CHALLENGE OF THE FUTURE

At DMAAC, we are moving toward a goal of complete digital mapping. Cartographers of the future will no longer compile charts on light tables, but with interactive cathode ray tube (CRT) viewers. Negatives will be photoengraved on computer driven coordinatographs. As the technology is perfected, press plates will be etched by computer driven laser beams.

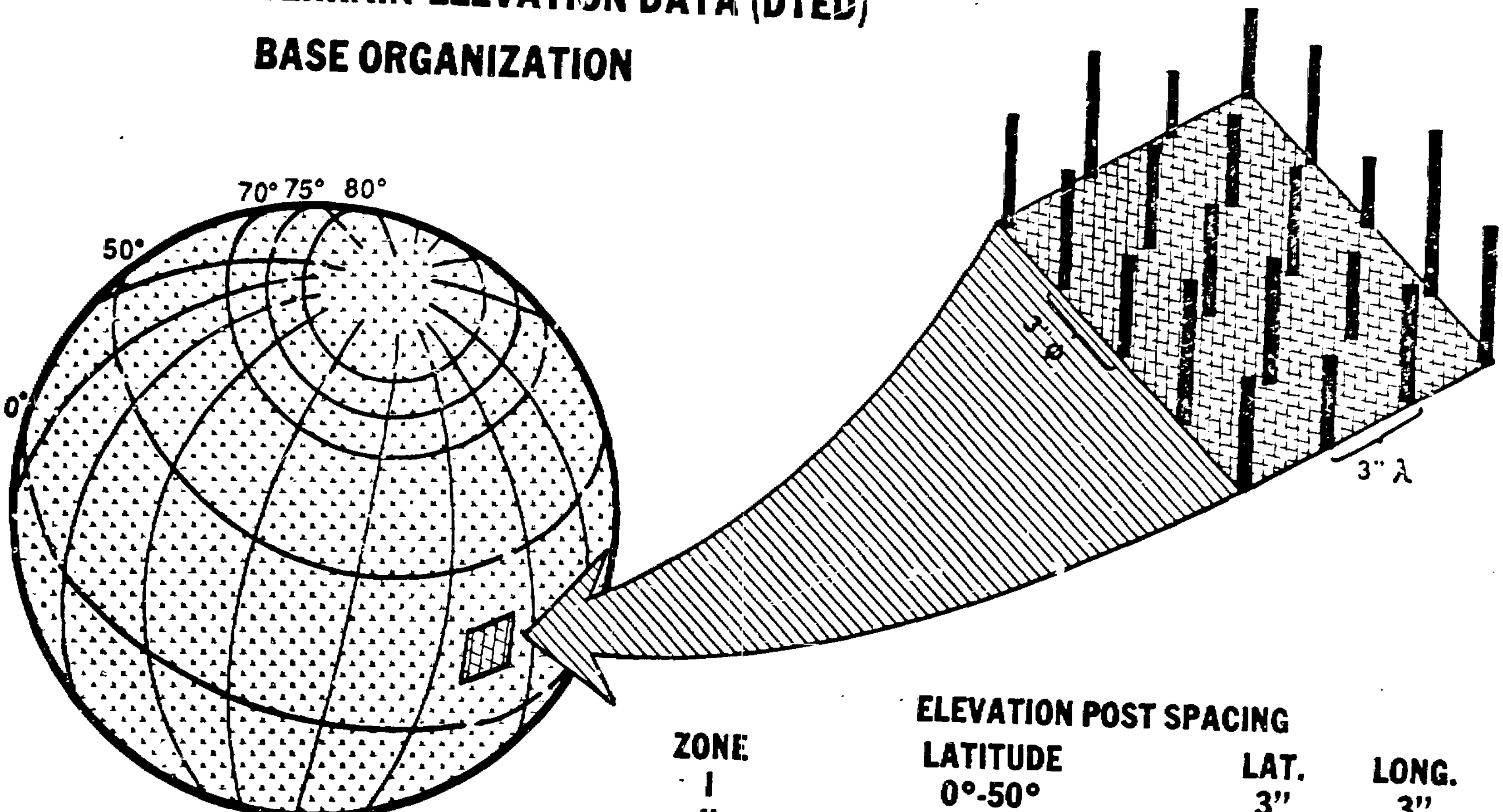
The computer contours generated at DMAAC with our current procedure require a minimum of light table manipulation. Although, the contours must be labeled and edited to verify their agreement with planimetric data. Engraving and platemaking are still done by traditional methods.

We are testing an interactive edit system which will allow cartographers to manipulate digital contour data. With the system, cartographers can eliminate blunders, remove insignificant tops and depressions and align contours to drainage. The system will place type and assign line weights. The linear data will be output on magnetic tape which in turn will drive a plotter to photographically expose the contour negative.

The state of the art in automatic contouring still requires the manual intervention of a cartographer. The challenge we face is to design a system in which the cartographer/computer interface is most efficient. The benefit is that our cartographers can more effectively apply their skills and allow the computer and automatic drafting tables to accomplish the routine drudgery to which they are best suited.

We, at DMAAC believe that automatic contouring from digital terrain elevation data is a significant step forward in automated cartography.

THE DIGITAL TERRAIN ELEVATION DATA (DTED) BASE ORGANIZATION



ZONE	LATITUDE	LAT.	LONG.
	ELEVATION POST SPACING		
I	0°-50°	3"	3"
II	50°-70°	3"	6"
III	70°-75°	3"	9"
IV	75°-80°	3"	12"
V	80°-90°	3"	18"

Figure 1

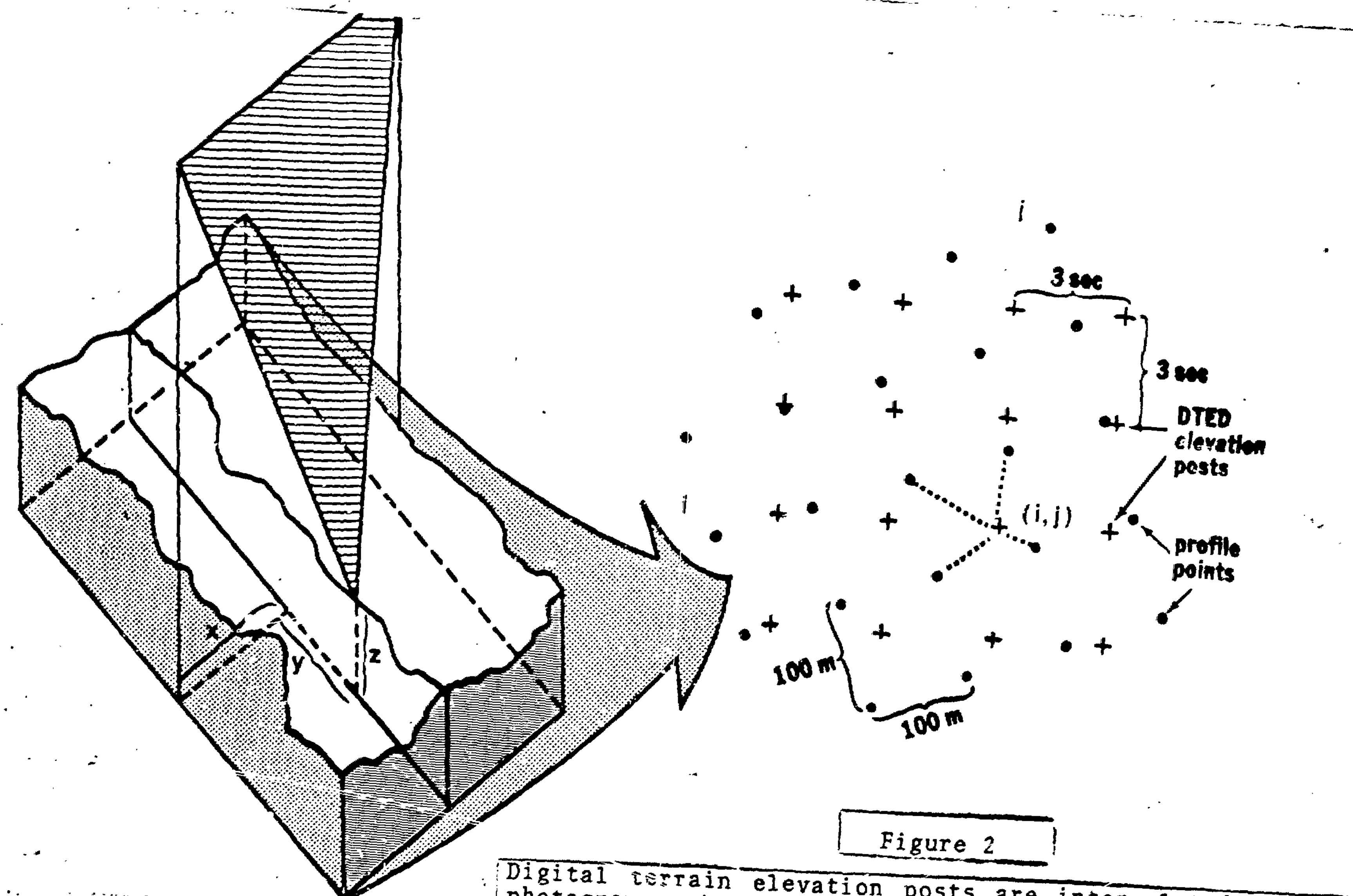


Figure 2

Digital terrain elevation posts are interpolated from the photogrammetrically derived X, Y and Z profile points.

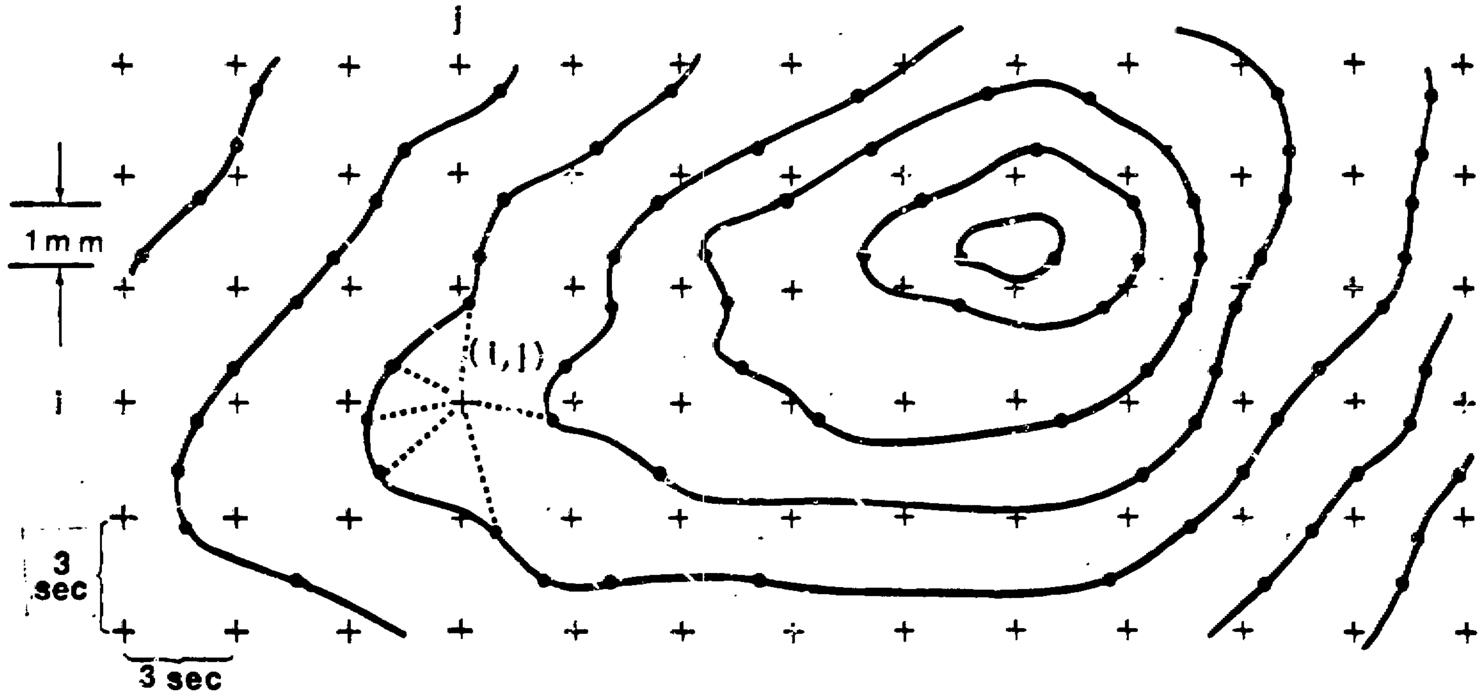


Figure 3
Digital terrain elevation posts are interpolated from digitized contours.

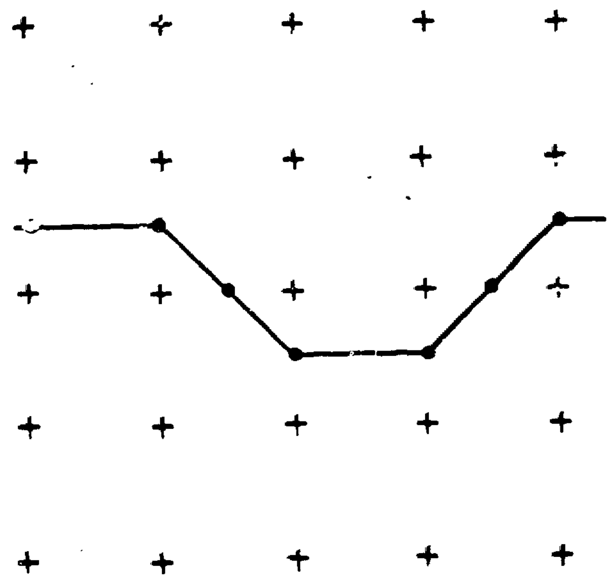


Figure 4
Contours are constructed from segments of lines passing between digitial terrain elevation posts.

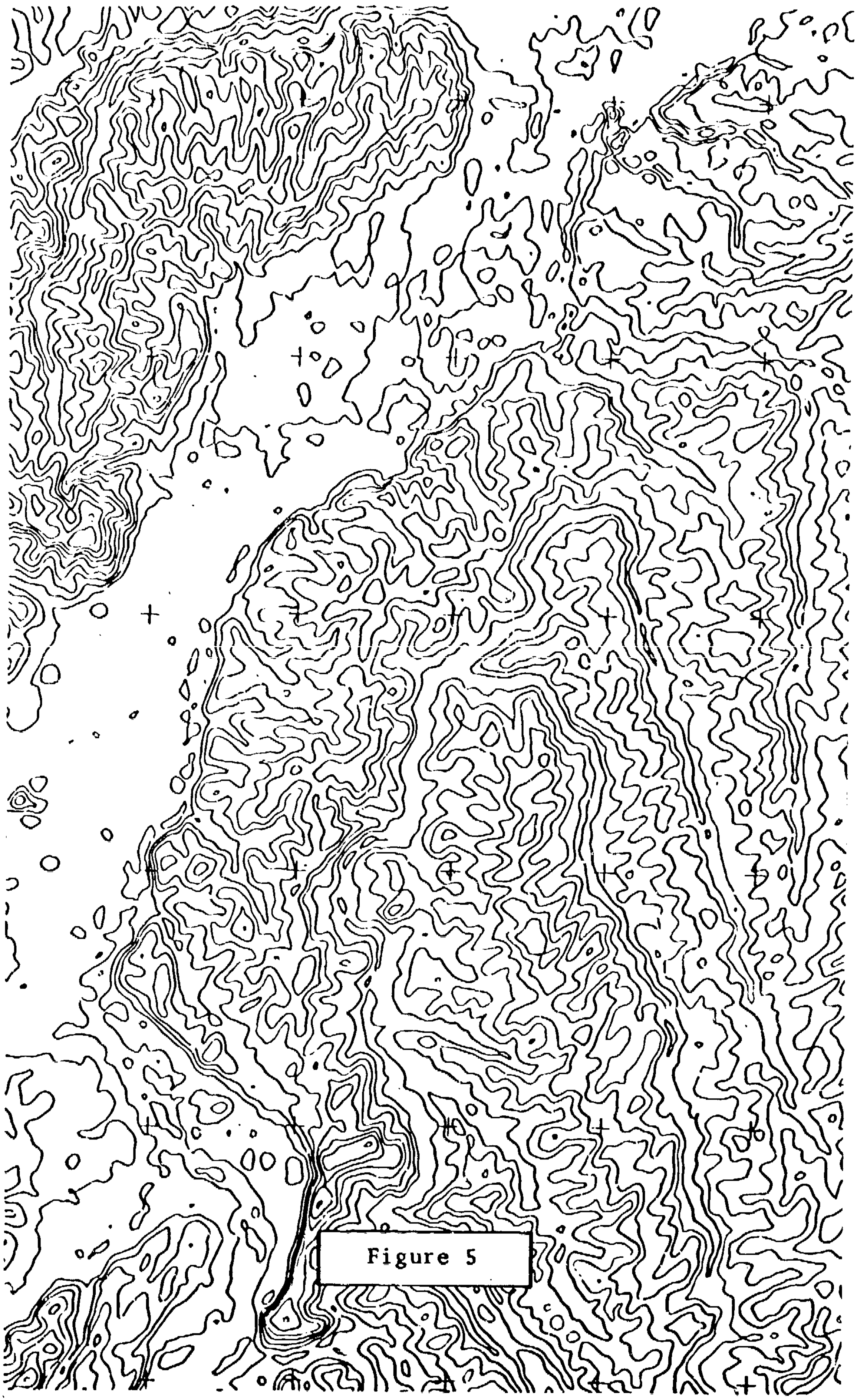


Figure 5